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# Optical identification of supersoft X-ray sources in M31

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**Abstract.**

We report on initial progress in a program of optical identification of supersoft X-ray sources in M31, pursued mainly with the WIYN telescope. We propose the identification of one supersoft X-ray source with a variable star, which we believe to have been a classical or recurrent nova in outburst in September 1990. The nova remnant must have been still a supersoft X-ray sources 5 years after this observation, when it was observed with ROSAT.

## 1. Introduction

16 supersoft X-ray sources (SuSo) were detected during the deep ROSAT PSPC pointings of M31 (Greiner 1996, Supper et al. 1997, Greiner 2000). Up to 18 other ROSAT sources in the direction of M31 have been proposed to belong to this class (Kahabka 1999). Most fields were subsequently observed with the ROSAT HRI and the positions are precise within 10-15 arcsec. It is crucial to determine the precise nature of this population and whether it is associated with M31. Yet, only 9 of the sources have been scheduled for CHANDRA observations, which will make the optical identification almost straightforward in most cases (thanks to arcsecond precision). For all the others, we have to rely on high quality optical data. The optical identification and the subsequent optical study of these sources is extremely necessary in order to increase our knowledge and the statistics of the extragalactic low mass X-ray binary population. Yet, the identification poses several challenges. We can assess that the optical counterpart belongs to M31 only by obtaining the spectrum (through the red shift of the spectral lines). However, the maximum absolute magnitude of the supersoft X-ray sources observed in the Galaxy and the Magellanic Clouds is $M_V$=-2 (see Greiner 2000 and references therein). Extrapolating to the distance to M31, we

expect the most luminous members of the class of the close binary supersoft X-ray sources described in van den Heuvel et al. (1992) or in Kahabka and van den Heuvel (1997) to be at V$\simeq$22. The spectra can be obtained mainly, even if not always, with very large telescopes of the new generation.

The starting point for optical identification of supersoft X-ray sources is, however, *optical photometry* (e.g. Orio et al. 1994, 1997). The supersoft X-ray sources are expected to be very "blue" and hot and be identified thanks to the color indexes (U-R, B-R, B-V), and often to the optical variability, mostly on time scales of few hours to a day. Among foreground sources even cooling neutron stars might be optical counterparts (if very faint and not showing binary-type variability, e.g. Walter et al. 1997), while apparently more luminous optical counterparts might be AM Her stars, other CV's, PG 1159 stars and VY Scl stars (see Greiner 2000). The latter are particularly interesting because they imply an exciting extension of the class of SuSo binaries to optically bright systems. Sources that truly belong to the M31 population are: exceptional planetary nebulae, symbiotic stars and novae shortly after thermonuclear runaways, and other close binaries. The latter belong to two different types: long period (0.5-2 days, like CAL 83 and 87, see van den Heuvel et al. 1992) and short period ones (with periods of $\simeq$ 4 hours, and expected to be intrinsically less luminous) like SMC 13 or RX J0537.7-7034 (e.g. Greiner et al. 1999). Finally, background sources are AGN, Seyfert and other active galaxies.

## 2. The optical imaging program with the WIYN telescope

Some of us (the first four authors in this paper) have started an imaging program of M31 with the WIYN 3.5 "new technology" telescope. Under the best conditions we have images that reach B$\simeq$24. Preliminary results indicate two likely candidates that should be studied spectroscopically. Moreover, we discovered a variable that we believe to have been a nova in M31. This nova is almost certainly the "culprit" of the supersoft X-ray emission. It was identified thanks to comparisons with a large number of images obtained over several years by two of us (P.L.N. and A.N.T.) and other published images in the literature. Up to now only 4 classical novae and one recurrent nova have been identified with supersoft X-ray sources. The existence of hot white dwarf after the outburst has very important consequences for the mechanisms and evolution of nova systems (see accompaining poster by Orio & Parmar).

## 3. Possible candidates

We still have very preliminary results for most sources we studied except RX J0044.0+4118. We identified possible candidates in the fields of RX J0039.7+4030 and RX J0046.2+4144, respectively at U$\simeq$22 and U$\simeq$20; however these candidates appear interesting for their U-R values and *not* for their variability. Monitoring the first of these two fields over almost 3 hours we could not detect any modulation in the optical magnitude of any of these candidates. For a galaxy with a reduced metallicity, like M31, we expect to find close binary SuSo of the type described by van den Heuvel et al., 1992, with orbital periods $\geq$12 hours. The $\simeq$4 hours orbital period binaries among SuSo are less likely to be members

Figure 1. The field of RXJ0044+4118 observed with the R filter at the WIYN telescope in August 1999: the arrow in the circle indicates the position of the 18th magnitude star observed in September 1990 by Magnier et al. (1992) and by Nedialkov and Tikhonov. The dimension of the image is about 3.4 arcmin.

of M31, and our sampling interval might have not been sufficient to detect modulations in the 0. While we plan monitoring the field over longer time periods, spectroscopic information would be very desirable.

## 4. An optical nova as possible counterpart

In the field of RX J0044+4118, we have instead identified an optically variable star, that we suggest to be a classical or recurrent nova, and also the optical counterpart of the supersoft X-ray source. In Fig. 1 we show the R image of the field and indicate the position where Magnier et al. (1992) detected an object at B=18.217 with color index B-V=0.187, at coordinates $\alpha$(2000)=00,44,04.71 and $\delta$(2000)=41,18,21.6 (1.7 arcsec away from the ROSAT position listed in the merged catalog in HEASARC), in observations done between September 12 and 27 1990. A few days later the same object was found to be at B=18.1 in a photographic plate taken at 1m telescope at SAO RAN in Russia on September 21 1990. The object does NOT appear in the blue POSS (limiting magnitude V$\leq$22) neither in plates taken in several previous and following years with the 2m telescope at of the Bulgarian Academy of Science at Rozhen in Bulgaria and with the 1m telescope at SAO RAN, Russia, (limiting magnitudes$\simeq$21), and finally not in WIYN images taken by us in August 1998 in U and R (the photometry was *complete* to a limit R$\leq$22, but several objects were still detected at magnitudes R$\simeq$24). We concluded that the identified variable was most likely a nova in M31, and that the supersoft X-ray source, detected in 1993, is associated with it. The position of the supersoft X-ray source was still measured in ROSAT HRI

observations in 1996, so at that time the nova must have still been "on" - i.e. the white dwarf was burning hydrogen in a shell. Given the optical magnitude observed in September 1990, the nova outburst must have occurred during that year and the hot remnant appeared as a supersoft X-ray source for at least 6 years. Statistical considerations on the frequency and location of novae in M31 suggest that the probability of a random coincidence is very small (e.g. Capaccioli et al. 1989).

## 5. Classical and recurrent novae as supersoft X-ray sources

Up to now only 4 classical novae and one recurrent nova in the Galaxy have been identified with supersoft X-ray sources. The existence of the hot white dwarf after the outburst has very important consequences for the mechanisms and evolution of nova systems (see accompaining poster by Orio & Parmar). Identifying classical or recurrent novae in M31 with SuSo allows much better statistics and gives us new insight into the secular evolution of nova systems.

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